II.

FOOD CONSERVATION FROM THE STANDPOINT OF THE CHEMISTRY OF NUTRITION.

By H. C. SHERMAN.

(*Read April 20, 1918.*)

Without repeating the reasons for the present program of food conservation which tends to shift the emphasis of consumption in this country toward the more perishable foods in order that a larger share of our wheat, meat, fats, and sugar may be saved for export to our army and the Allies, let us consider from the standpoint of the chemistry of nutrition whether such a change in our food habits will involve any sacrifice or rather an improvement in the average American dietary.

Recent research in nutrition puts us in position to face such problems with more confidence than would have been justified even a few years ago. Until very recently, students of the chemistry of nutrition were in the embarrassing position that rations made up by mixing in the purest forms all the substances known to be necessary never proved permanently adequate for the nourishment of experimental animals. With the discovery of food hormones or vitamines, the correlation of chemical structure and nutritive function among the proteins, and the fuller investigation of the rôle of the inorganic elements, we now believe that everything needed for normal nutrition has been apprehended and can be reckoned with, though in the case of the food hormones or vitamines the chemical identification is not yet complete.

The quantities of the various nutrients which are needed daily by the body for its normal nutrition have also been studied, with the result that each "requirement" may be stated in more or less definite quantitative terms. Thus the total food requirement (or energy requirement) in calories per man per day; the requirement

for protein, or for any individual element, in grams per man per day. The "vitamine" requirement cannot be stated in terms of actual weight either of "fat-soluble A" or of "water-soluble B," but the percentages of certain foods, rich in the one or the other or both of these dietary essentials, which suffice to make an otherwise satisfactory diet adequate for normal growth and reproduction in laboratory animals have been determined for a sufficient number of cases to enable us to take account of this factor of food value in considering the prominence which should be given to each type of food in planning an adequate and economical diet.

The quantities of nutrients required for normal nutrition as determined by laboratory experiments may be compared with the average quantities actually consumed in typical American dietaries, to find whether our ordinary food habits ensure us reasonable and proportionate margins of safety with reference to each nutritive requirement—in other words a diet well balanced from the standpoint of our present knowledge of nutrition, the older and simpler criteria of balanced diet having now been outgrown.

If in addition to such a comparison of actual nutritive requirements with the quantities of nutrients furnished in the usual food supply, we take account also of the kinds and amounts of the individual articles or types of food and the relation which each bears to the whole amount of food consumed, both as regards its cost and its contribution to each of the elements or factors of food value, we shall be able to judge with considerable confidence the nutritional significance of such a shifting of food habits as is contemplated in the program of the Federal Food Administration.

Most prominent in this program is the saving of wheat.

By people of comfortable income, wheat-saving may be accomplished by simple reduction in the amount of bread consumed. The bread thus withdrawn from the diet of the well-to-do may or may not be replaced by perishable food depending upon whether or not it is necessary or desirable to keep up the calorie value of the diet, and the weight of the body. In either case the ration with the reduced allowance of bread will usually be as well balanced as before.

But among those who must consider the cost of their food, the

attempt to reduce materially the amount of bread consumed will often be much more difficult, and to limit the poor to a per capita allowance of bread as small as that to which the wealthy can easily limit themselves would involve both hardship and injustice.

People of low income naturally and properly live more largely upon bread, because it usually furnishes more food value in proportion to its cost than any other prominent article of diet. For this reason the saving of wheat in the homes of the many can best be effected by teaching them not to eat less bread but less wheat in their bread.

Because so many of our people must for economic reasons depend so largely upon breadstuffs, it seems of the utmost importance to determine as conclusively as possible the nutritive efficiency of the chief wheat substitutes as compared with wheat itself.

A study of corn in this respect appeared particularly desirable, because it is so much the most important quantitatively of the grains which can be substituted for wheat and at the same time the one whose equal value with wheat is perhaps the most apt to be questioned, especially as regards its digestibility and the nutritive efficiency of its proteins.

In the experience of our laboratory,[1] the abrupt substitution of a large amount of corn meal for wheat flour, has sometimes, though not necessarily, been followed by slight disturbance or discomfort of digestion, but in all cases the corn protein has shown essentially the same efficiency in nutrition as has the protein of wheat. Such unfavorable effects upon appetite or digestion as were attributed to corn meal may have been due to the methods of preparing the corn products or to the fact that the diet as a whole was too bulky and too starchy for the summer weather in which the earlier of our experiments were performed.

Not only the time and temperature of cooking but also the final texture of the material may be a factor of some importance to its digestibility. The porous texture of our ordinary wheat bread favors the absorption of large quantities of saliva as the bread is

[1] The experiments with human beings here referred to were all made upon healthy adults and relate to requirements for maintenance, not for growth or reproduction.

chewed, while soft or very crumbly corn bread (or corn meal mush) may be swallowed without such thorough insalivation, and be less readily digested for this reason. By baking corn bread in thin scones it is possible to secure thorough and uniform cooking of the starch and a final product hard enough to induce thorough mastication and admixture with saliva before swallowing. Thus prepared and eaten, corn meal has in our later experiments replaced wheat flour entirely with no detriment whatever to the ease and comfort of digestion, even though the corn bread was the chief part of the diet.

Recently we have completed an experiment in which a young woman of average weight (56 kilograms), not previously accustomed to any considerable use of corn foods, has substituted such corn bread for all other bread stuffs and cereals for a month with no disturbance whatever of appetite or digestion, and has maintained nitrogen equilibrium throughout the month on a diet furnishing only 36 grams of protein daily, of which three fourths was the protein of corn meal. Practically one fourth of the total protein was furnished by milk and an insignificant amount by apple. Small amounts of sugar and of filtered butter fat were used to bring the fuel value of the diet up to the energy requirement. The subject felt excellently nourished and was ready at the first opportunity to begin a similar experiment even with the diet still further restricted by omission of the milk. During 16 days on a ration of corn meal, apple, butter-fat, and sugar, furnishing only 4.38 grams of nitrogen or 27 grams of protein (equivalent to 34 grams for a man of 70 kilograms) practically all of which was maize protein, the loss of body nitrogen was only about one half gram per day.

It is evident from these experiments that the conclusion of Karl Thomas, often quoted on Rubner's authority, which attributed a much lower value to maize protein, was erroneous. In meeting the maintenance requirements of adult human nutrition, the protein of corn meal has here shown as high an efficiency as has been reported by other investigators for wheat protein or for the average protein of ordinary mixed diet. The well-established differences of nutritive efficiency among proteins, corresponding to their differences in chemical structure, are fully recognized but are more significant for growth than for maintenance. Moreover we are here discussing

the proteins of corn as compared with wheat (not as compared with milk proteins which are certainly more efficient in nutrition). That potato protein is similarly efficient has been shown by Hindhede and by Rose and Cooper. Thus the findings of research in the chemistry of nutrition indicate that the nutritive value of the diet will be fully maintained when corn or potato is substituted for wheat. Even if such substituion results in a small diminution of the amount of protein consumed, there will still be an ample margin above the most liberal estimate of actual nutritive requirements.

Granted that corn products can be substituted for the corresponding products of wheat to any desired extent without diminution of food value as determined by carefully controlled experiments of a month's duration, the question may still arise whether the results would be equally favorable in case the substitution of corn for wheat were continued much longer and in the case of growing as well as full-grown persons. This question cannot well be answered directly by experiments upon human beings—if for no other reason than that a research cannot be prolonged indefinitely and still be completed in time to be of use in connection with the present emergency work of food conservation. But an adequate answer appears to be furnished by the investigations of McCollum in which laboratory animals (chiefly rats) have been kept on experimental diets of wheat or corn with the necessary supplements often for their lifetime and in many cases for more than one generation. Such experiments should bring to light any differences which might be conceived to exist in the most elusive factors of food value or in the general wholesomeness of the two grains. In recent summaries of the results of such research, McCollum has repeatedly stated that wheat and maize are essentially alike in their dietary properties. If this seems surprising in view of the well-known inadequacy of zein when fed as the sole protein of the diet, it should be recalled that Osborne and Mendel, to whom the knowledge and explanation of this deficiency of zein is so largely due, have also shown that the other chief protein of corn, maize glutelin, is adequate to meet all protein requirements and to maintain a normal rate of growth in the young. They have also shown beautifully that zein, while inadequate alone, may yet take the major part in meet-

ing the protein requirements, either of maintenance or of growth, when it is supplemented by even a small amount of milk protein.

That the supplementing of the grain protein by milk is of greater importance during growth than in the mere maintenance of a full-grown person is fairly obvious from the fact that in the latter case it is only necessary to maintain an already established equilibrium between tissue protein and amino acids. *Any* of the amino acids whose radicals are contained in tissue proteins may be expected to function in such maintenance, whereas there can be no growth unless *all* the amino acids represented in tissue proteins and not formed in the body are present in suffiicent abundance.

Even in the case of the full-grown organism persistent use of a diet consisting *too exclusively* of grain products, or seeds of any kind, may lead to unfavorable results, but this is true of wheat as well as corn and is no objection to the substitution of the one for the other.

Such substitution of corn (and presumably of other grains) for wheat will leave practically unchanged the nutritional efficiency of the diet and the usual margin of safety above actual requirements which is characteristic of the average American food supply.

What then is this margin in the case of the different factors of food value and how will it be affected by the other substitutions which the present food situation demands?

In view of the findings just presented by Dr. Benedict and the fact that in most food studies outside of the laboratory it is not practicable to make accurate record of the muscular activities of the persons concerned, any attempt to estimate the percentage by which the total food intake of the average American family exceeds its actual food requirement as expressed in calories, would necessarily involve several assumptions the discussion of which would extend the present paper beyond its assigned limits.

In the study of protein requirement the assumptions are fewer because muscular activity is here not an appreciable factor, but the data of different investigations are less concordant than in the study of energy metabolism. The results of a review of the literature of protein requirement up to 1917 with an attempt to select the experimental data which are comparable with each other and applicable

to the problem of the amount of protein actually needed for normal human nutrition have recently been discussed elsewhere.[2] The average of the "requirements" indicated in the 86 experiments which seemed to be applicable under the necessarily somewhat arbitrary criteria adopted for the sake of minimizing the personal equation in selection and interpretation of results, was 49.2 grams (or say 50 grams) per man per day, which agrees almost exactly with Chittenden's estimate based chiefly upon the results of his own experiments. Thus the net result of all subsequent work up to date does not differ materially from Chittenden's findings of a decade ago. This may be accepted as the best evidence yet available regarding the amount of protein actually required in normal human nutrition without entering upon any discussion of the question as to how much more than this it is desirable to consume. In other words in speaking of the requirement we imply nothing as to the best dietary standard for protein.

As compared with this actual requirement of not over 50 grams, the average amount of protein in typical American dietaries, as judged from the 250 studies of families or larger groups the data of whose food consumption has been most fully worked out, is 106 grams per man per day. The average of typical American dietaries thus shows in its protein content a margin of safety of 112 per cent.

Of the inorganic elements essential to nutrition, most are believed to be furnished in abundance by the ordinary American food supply with the table salt commonly added to it, but recent research has shown that three of these elements cannot properly be dismissed with this assumption. These are phosphorus, calcium, and iron.

It is sometimes stated that our knowledge of the amounts of these elements required in nutrition is so meager as to make the interpretation of dietary data more difficult here than in the case of protein. Until recently this was true of all three of these elements and it is still true of iron; but the quantitative metabolism of phosphorus and calcium has lately been investigated with sufficient thoroughness so that we now know the normal nutritive requirement for these elements with about the same degree of accuracy as we know the protein requirement and can estimate the margin of safety

[2] Lecture before the Harvey Society, New York, Jan. 12, 1918.

in the average dietary and the likelihood of deficiency in individual cases as well for phosphorus and for calcium as for protein.

The phosphorus "requirement" as indicated by the results of 87 experiments averages 0.88 gram per man per day,[3] and the average amount in 250 American dietaries was 1.60 grams, a margin of 82 per cent.

The calcium "requirement" indicated by 63 experiments averages 0.45 gram,[3] and the average amount in typical American dietaries was 0.74 gram, a margin of 64 per cent.

It will be seen that the margin of average consumption above the bare requirement is less for phosphorus than for protein, and narrowest in the case of calcium. Actual deficiencies in the sense of a rate of consumption below the average of the bare requirements for normal maintenance, are exceedingly rare in the case of protein, not so rare in the case of phosphorus, much more frequent in the case of calcium. It appears that the American dietary is more often deficient in calcium than in any other chemical element whose metabolism has been studied.

Probably because of the ability to transfer calcium from the bones to the soft tissues, the body may continue to lose this element for a long time as Forbes and Beegle have shown strikingly in the case of milch cows. But it does not follow that the loss of body calcium is to be regarded with indifference. Mendel has written regarding his recent experiments that "animals may be in excellent nutritive condition in so far as protein is concerned for long periods of time while they are still losing calcium from their bones. It then happens that suddenly a collapse comes for which there is frequently no obvious explanation." And McCollum has found in his studies of laboratory animals that it is largely because of insufficient calcium that such animals do not show normal nutrition when kept continuously upon rations consisting too exclusively of seeds. Our investigations based chiefly upon the chemical analysis of the entire intake and output of the human organism, while quite different in method, have led to the same view regarding the importance of calcium as has been reached by Mendel and by McCollum.

[3] These phosphorus and calcium "requirements" are derived in the same manner as the protein "requirement" of 50 grams per man per day explained above.

American dietaries, both urban and rural, are more likely to be deficient in calcium than in any other individual element because they tend to consist too largely of the products of seeds together with meats, fats, and sugar with too small a proportion of milk and vegetables.

All meats are very poor in calcium; purified fats and sugar are practically devoid of it. On the other hand milk, eggs and green vegetables are rich in calcium; other vegetables and fruits contain it in fairly liberal amounts. Hence decreased consumption of meats, fats and sugar, with increased use of milk, eggs, vegetables and fruit will constitute an important improvement in the typical American dietary.

Detailed study of the data of the 250 typical American dietaries already mentioned shows plainly that as the relative expenditure for meats, fats, and sugar decreases and that for perishable foods increases the dietaries become more adequate and better balanced as regards the various factors of food value which can be expressed in quantitative terms—energy value, protein content, and amounts and proportions of the various ash constituents or inorganic elements.

So far as calcium and the other inorganic elements are themselves concerned, they might be supplied in the form of simple mineral substances such as calcium phosphate, but in human dietetics it is more feasible to teach the use of familiar than of unfamiliar articles, and by the use of sufficient milk and vegetables to provide a liberal supply of calcium the diet is improved in other respects as well.

The larger use of such perishable foods as milk, vegetables and fruit is beneficial in several directions which as yet are not susceptible of quantitative measurement—such properties as the promotion of growth, and the prevention of neuritis, scurvy and pellagra, whether the latter be strictly nutritional diseases or not. Such benefits are probably due in part to the unidentified essential substances "fat-soluble A" and "water-soluble B" both of which occur abundantly in milk, eggs and many vegetables, and in part to those chemical and physical properties of fruit, vegetables and milk which are favorable to intestinal hygiene and so protect the body from objectionable products of intestinal putrefaction.

It has long been known but perhaps never sufficiently emphasized that the milch cow returns for human consumption a much larger proportion of the food value of what she eats than does the animal which is raised for slaughter. This is strikingly true not only of the previously recognized factors of food value but also, and apparently to an even larger extent, of the so-called vitamines. These are contained in abundance in green leaf fodders such as grass and hay. The vitamines thus consumed are stored in the animal tissues to only a limited extent, but are transferred in relative abundance to the milk. Thus the vitamines of coarse materials not directly available as human food are brought into form for man's use, very efficiently through milk production, very inefficiently through the production of meat. Not only is milk the most economical intrinsically of the animal foods of farm origin, but of even greater interest is the positive demonstration by fully controlled experiments like those of Osborne and Mendel and of McCollum, that a liberal use of milk in the diet is the best safeguard against any deficiency which might possibly arise through restricted choice of foods and the safest way to ensure that the consumption of enough food to supply the energy needed shall meet all other requirements of nutrition as well.

Thus in bringing a larger share of our corn crop directly into human consumption and in giving to such perishable foods as milk, vegetables and fruit a more prominent place in the diet, we shall be working toward permanent improvements in our national food economy at the same time that we save the wheat, meat, fats and sugar which are needed for our armies and the Allies.

LABORATORY OF FOOD CHEMISTRY,
COLUMBIA UNIVERSITY,
April, 1918.